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# Forecasting Research

Forecasting Research Division
Technical Report No. 175

# Results from a parallel trial to investigate the use of METEOSAT water vapour SATOBs

by

J R Leighton

August 1995

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## 1.Introduction

Satellite cloud-track winds (SATOBs) have been used in Numerical Weather Prediction (NWP) models for a number of years with several improvements being made to their quality. In the last few years water vapour (WV) data has been used for tracking purposes to produce SATOB data in the upper levels (400 hPa and higher) and from November 1994, the UK Meteorological Office (UKMO) started reception of the METEOSAT-WV data. WV wind vectors are found by tracking structures in WV imagery with height assignment being accomplished using co-located radiances from the infra-red (IR) channel.

The UKMO currently uses SATOBs derived from the IR channels of GOES and METEOSAT and the IR and visual channels of GMS for assimilation into its models.

Monitoring of SATOBs from the METEOSAT-WV channel initially indicated that the data had a relatively large positive speed bias compared with the Global Model. Close investigation showed that the statistics are heavily weighted by observations over the tropics. Around 66% of the data are located within 20° of the equator and they have a positive speed bias of around 2 m $s^{-1}$. Comparison with aircraft data over the same latitude bands suggests that the model background field could be in error by a similar amount. Figure 1 shows the mean Observation minus Background (O-B) windspeed for aircraft observations between the heights 70 and 500 hPa for May 1995 from the Operational Run showing differences of about 2 m $s^{-1}$ in the equatorial region.

The following report follows similar lines to Radford, 1994 which reported on proposed changes to the SATOB rejection list.

## 2. The Parallel Trial

The Parallel Suite was used to assess the impact of assimilation of METEOSAT-WV winds on the global model analysis and forecast. The experiment ran from 4-30 May 1995, with a 5-day forecast being run each day from the 12 UTC analysis. An Observation Processing Database (OPD) was produced from each data assimilation cycle. Figure 2 shows O-B statistics for METEOSAT- IR and WV SATOBs during the trial period. The higher bias of around 1.5 m $s^{-1}$ is evident for the WV SATOBs (figure 2a). The RMS O-B Vector Wind Error (figure 2b) is larger for the WV SATOBs probably because part of the error will be due to the error in the wind vector and part associated with selecting the correct feature in the IR image on which the height assignment is performed. There are significantly more observations from the WV channel (figure 2c) and the percentage flagged data is also lower (figure 2d).

## 3. Verification

### 3.1 OPD comparison

The OPD holds data on observation minus background (O-B) differences. Statistics derived from these data may be interpreted as a verification of the 6-hour forecast (background). In Table 1, the root mean square vector wind (rmsvw) O-B differences are given for all AIREPs reporting between 100 to 400 hPa, and for all radiosondes and pilot balloons at the standard levels of 250 hPa, 500 hPa, 700 hPa and 850 hPa. The statistics have been divided into three latitude bands, 30° from the equator.

| | NH | | Tropics | | SH | |
|---|---|---|---|---|---|---|
| Level | Oper | Trial | Oper | Trial | Oper | Trial |
| AIREPs | 6.87 | ***6.80*** | 5.98 | ***5.97*** | ***7.06*** | 7.19 |
| 250 hPa | ***5.88*** | 6.07 | ***6.47*** | 6.61 | ***9.08*** | 9.22 |
| 500 hPa | ***4.55*** | 4.58 | ***4.35*** | 4.57 | 8.72 | ***8.26*** |
| 700 hPa | ***4.02*** | 4.11 | ***4.23*** | 4.36 | ***6.50*** | 6.66 |
| 850 hPa | ***3.91*** | 3.98 | ***3.98*** | 4.09 | ***6.16*** | 6.38 |

Table 1: Root mean square vector wind O-B differences (m $s^{-1}$) for all AIREPs reporting between 100 hPa and 400 hPa and radiosonde data at selected levels. Lower (better) values are highlighted in ***bold.***

As indicated in the introduction and shown in figure 1, monitoring has shown that the METEOSAT-WV and AIREP winds would appear to have a positive bias of approximately 2 m $s^{-1}$ in the equatorial region. It would therefore seem reasonable that the 6-hour forecast would be drawn towards the AIREP data on including METEOSAT-WV data in the trial. This would appear to be the case, at least in the Northern Hemisphere and the Tropics with marginally lower RMS vector wind errors in the trial. The comparison with AIREP data in the Southern hemisphere is worse for the trial, probably as there are so few of these data in this region.

In all cases, bar one, the trial is worse for radiosonde data, indicating that the METEOSAT-WV winds have degraded the 6-hour forecast. The exception is at the 500 hPa level in the Southern Hemisphere. The degradation is to be expected since adding any extra data to the assimilations, in this case METEOSAT-WV, to the radiosonde data will automatically degrade any comparison made against the radiosondes.

O-B verification statistics were also calculated for SATOB winds, but are not shown here (the O-B time series have been shown in figure 2). As would be expected, rmsvw differences for the upper level winds are markedly lower (by more than 15%) in the trial than in the operational forecasts.

3.2 Verification against observations

The verification scores presented in the following tables follow the procedure that has been used in reporting results from previous parallel trials by FR Division (e.g. Bell, 1994). The verification score, the percentage change in the root mean square (rms) error is defined as:-

100% * (operational score - trial score)/(operational score)

so a negative value indicates a poorer performance in the trial.

The results are presented for geopotential height, vector wind, and temperature at 850 hPa, 500 hPa and 250 hPa and pressure at mean sea-level. The results are also split into the three latitude bands:-

- Northern Hemisphere (90°N-30°N) - Table 2
- Tropics (30°N-30°S) - Table 3
- Southern Hemisphere (30°S-90°S) - Table 4

Radford, 1994 points out that there are certain limitations in the verification system. All scores, apart from pmsl, are calculated by comparing with radiosonde observations, and these are mainly over continental areas and are poorly distributed in the southern hemisphere. Also SATOBs are only produced within 55° latitude of the equator, whereas the verification includes observations outside this area.

| | T+0 | T+24 | T+48 | T+72 | T+96 | T+120 |
|---|---|---|---|---|---|---|
| H850 | -0.4 | ***-2.1*** | ***-1.1*** | ***1.3*** | -0.4 | ***1.7*** |
| H500 | 0.0 | -0.2 | -0.1 | ***1.0*** | ***-0.5*** | ***1.8*** |
| H250 | ***0.5*** | ***0.5*** | ***1.0*** | ***0.8*** | -0.4 | ***1.5*** |
| T850 | -0.4 | 0.0 | 0.0 | 0.2 | ***-0.6*** | ***1.0*** |
| T500 | -0.1 | ***-0.8*** | ***-0.6*** | 0.1 | 0.0 | ***1.0*** |
| T250 | 0.0 | ***-1.2*** | ***-0.9*** | 0.3 | ***0.5*** | ***1.2*** |
| W850 | 0.0 | ***-0.6*** | ***-0.5*** | ***0.6*** | -0.3 | ***0.8*** |
| W500 | 0.0 | -0.3 | -0.3 | 0.2 | -0.4 | ***0.9*** |
| W250 | 0.0 | -0.1 | 0.1 | 0.4 | -0.4 | ***1.7*** |
| PMSL | 0.0 | -0.3 | ***-0.5*** | 0.3 | ***-0.6*** | -0.2 |

Table 2: Percentage change in rms verification score for the northern hemisphere. Changes of at least 0.5% are highlighted in ***bold.*** Positive values indicate an improvement in the trial.

Over the Northern Hemisphere (Table 2) the impact is slightly in favour of the trial, especially at later forecast periods. Of the 27 scores with absolute scores greater than or equal to 0.5%, 17 are in favour of the trial, 14 of these for forecast of T+72 and later. The impact on the analysis is neutral for the majority of the variables and heights, with a negative impact for the lower two levels for temperature and the lowest level for height and a positive impact at the highest level for height. Of the forecasts, the

impact is generally negative for forecast at T+24, T+48 and T+96, but positive impacts at T+72 and T+120, particularly for the heights. The impact on the heights at 250 hPa is positive in the analysis and all but one of the forecast periods.

| | T+0 | T+24 | T+48 | T+72 | T+96 | T+120 |
|---|---|---|---|---|---|---|
| H850 | 0.0 | ***-1.5*** | ***-1.3*** | ***-0.5*** | -0.4 | ***0.9*** |
| H500 | 0.3 | -0.4 | -0.4 | 0.4 | -0.4 | -0.4 |
| H250 | 0.3 | ***0.9*** | 0.3 | ***0.6*** | ***0.5*** | ***3.2*** |
| T850 | 0.4 | ***0.8*** | 0.1 | ***1.8*** | 0.4 | ***1.3*** |
| T500 | 0.3 | 0.2 | 0.3 | -0.4 | ***0.6*** | ***1.6*** |
| T250 | 0.3 | ***1.4*** | ***1.5*** | ***0.7*** | 0.4 | ***2.4*** |
| W850 | 0.1 | 0.2 | ***0.6*** | ***0.7*** | -0.1 | ***1.4*** |
| W500 | 0.2 | ***0.6*** | ***0.6*** | ***0.9*** | ***-0.7*** | ***-0.5*** |
| W250 | ***-1.4*** | ***1.9*** | ***2.1*** | ***0.7*** | -0.3 | ***1.3*** |
| PMSL | -0.1 | 0.1 | 0.1 | 0.3 | -0.2 | ***0.5*** |

Table 3: Percentage change in rms verification score for the tropics. Changes of at least 0.5% are highlighted in ***bold.*** Positive values indicate an improvement in the trial.

Over the tropics (Table 3), of the 33 verification scores with absolute values greater than or equal to 0.5%, 25 show a positive impact with the strongest being at the longest forecast of T+120. The scores in the analysis are generally slightly positive, with only one strong negative impact which is for wind at 250 hPa. The only strong negative impacts for the forecasts are for heights at 850 hPa for forecasts between T+24 to T+96.

| | T+0 | T+24 | T+48 | T+72 | T+96 | T+120 |
|---|---|---|---|---|---|---|
| H850 | 0.3 | 0.4 | ***1.7*** | ***0.9*** | ***-2.7*** | ***-1.6*** |
| H500 | -0.1 | ***1.2*** | ***1.2*** | ***1.2*** | ***-2.1*** | ***-0.9*** |
| H250 | 0.2 | ***0.9*** | ***0.8*** | ***1.7*** | 0.1 | 0.1 |
| T850 | -0.3 | ***0.5*** | 0.3 | 0.0 | ***-1.8*** | -0.4 |
| T500 | ***-1.3*** | -0.2 | ***1.0*** | ***0.5*** | 0.1 | ***-0.5*** |
| T250 | ***-1.3*** | 0.4 | 0.3 | ***-1.0*** | ***1.4*** | ***2.3*** |
| W850 | 0.3 | ***-0.8*** | ***-0.5*** | ***-0.8*** | ***-1.2*** | ***-2.7*** |
| W500 | 0.1 | ***2.5*** | ***1.5*** | -0.2 | ***-0.7*** | ***-2.1*** |
| W250 | -0.3 | -0.2 | 0.0 | 0.2 | -0.2 | ***-1.2*** |
| PMSL | 0.1 | 0.3 | ***0.5*** | 0.2 | 0.3 | ***-0.7*** |

Table 4: Percentage change in rms verification score for the southern hemisphere. Changes of at least 0.5% are highlighted in ***bold.*** Positive values indicate an improvement in the trial.

The impact over the southern hemisphere (Table 4) is neutral with 16 positive scores out of the 34 scores with absolute values greater than or equal to 0.5%. There are generally positive impacts for heights in the early forecasts and negative impacts for winds at T+120 and heights at T+96.

3.3 Subjective comparison

As in Radford, 1994, charts were produced for each forecast of differences between the operational and trial runs for a number of parameters. It was difficult finding any cases which showed obvious patterns of improvement or deterioration in the analyses or forecasts. Some analysis differences were found, one of which will be discussed in more detail below, the remainder probably being characteristics of the contouring algorithm rather any effect of the extra data being made available. However these differences soon declined in the early forecasts. As found by Radford,1994, differences built up in later forecasts, in particular over the southern oceans, in areas where there were limited data to verify against.

Of the analysis differences, one case has been selected for discussion. Plots of observations were produced using the workstation facility OPDPLOT (developed by B.Ingleby, FR Division).

12 UTC 18 May 1995

Figures 1 and 2 show the 250 hPa isotach analyses for the operational and trial runs respectively for 12 UTC 18 May 1995. A significant difference in the position of the jet may be seen over central Egypt, centred at 24°N 31°E in the operational run and repositioned further west with a similar strength, over eastern Libya in the trial run.

Figure 3 shows all the data available to the operational run in the layer 350-150 hPa between 09 UTC and 15 UTC on 18 May 1995. There are no observations within the jet core, but the nearest are SATOBs of METEOSAT-IR winds to the south with identifiers '000005' and radiosonde winds to the north and east of The Red Sea.

Figure 4 is the same as figure 3 but for observations available to the trial in the same height and time window. To the south of the jet core there are now several more SATOBs, namely from the METEOSAT-WV channel, identifier '0000025'. The most noticeable additional observations in this region are westerlies of 60 knots at 20°N 22° E and of 30 knots at 30°N 22°E, both from the METEOSAT-WV channel supporting nearby METEOSAT-IR observations, resulting in repositioning the jet further west. There were no radiosonde or aircraft observations nearby which agreed with or disputed the SATOBs.

The potential for improving the location and probably the strength of sub-tropical jets by assimilation of SATOBs from METEOSAT-WV is shown in this example.

## 4. Conclusions and Recommendations

Of the three latitude bands, the greatest impact in the trial was in the tropics, where most of the METEOSAT-WV SATOBs are found. There was a slight positive impact

in the northern hemisphere and a mixed impact in the southern hemisphere, being better for heights in the early forecasts and worse for winds in the later forecasts. Bearing in mind the verification is conducted against radiosonde data, the introduction of another data source into the analysis will degrade the verification.

The additional cost of processing the METEOSAT-WV SATOBs amounts to an average increase of approximately 20 seconds CPU time for the relevant subroutines, and an average overall increase of approximately 0.25% in the CPU time for the global model forecast run.

Given that there were few obvious cases for subjective comparison and the one case discussed, showed that the extra observations from METEOSAT-WV SATOBs helped to position a jet core, and, overall, a positive impact was found in the verification, it is recommended that METEOSAT-WV SATOB data be used in assimilations with the same restrictions that applied during the trial and which operationally apply to METEOSAT-IR SATOBs resulting in only high level (400 hPa and higher) data being used.

## 5. Acknowledgements

The experiment was completed with the help of J.Heming and B.Little (CF5) who set the experiment up, S.Bean (CF4), who scheduled and ran it. J.Heming also assisted in setting up OSCAR PLOT on the workstation for the analysis of the fieldsfiles and B.Ingleby (NWP) developed the OPDPLOT for observation plotting on the workstation. S.Bell (NWP) provided the verification software and useful comments on the draft version

## 6. References

Bell, R.S., 1994: "An operational trial to validate the use of Balanced Mass Increments derived from Assimilation Wind Increments." Forecasting Research Technical Report No.88, March 1994.

Radford, A.M.R., 1994: "Results from a parallel trial to investigate the use of satellite cloud-motion winds." Central Forecasting Technical Note No.20, July 1994.

## List of Figures


1. Mean O-B Windspeed for aircraft between 101 hPa and 400 hPa for May 1995

2.a) SATOB Mean O-B Windspeed between 101 hPa and 400 hPa during the trial
b) SATOB RMS O-B Vector Wind Error between 101 hPa and 400 hPa during the trial
c) SATOB Number of Observations between 101 hPa and 400 hPa during the trial
d) SATOB Percentage Flagged Observations between 101 hPa and 400 hPa during the trial

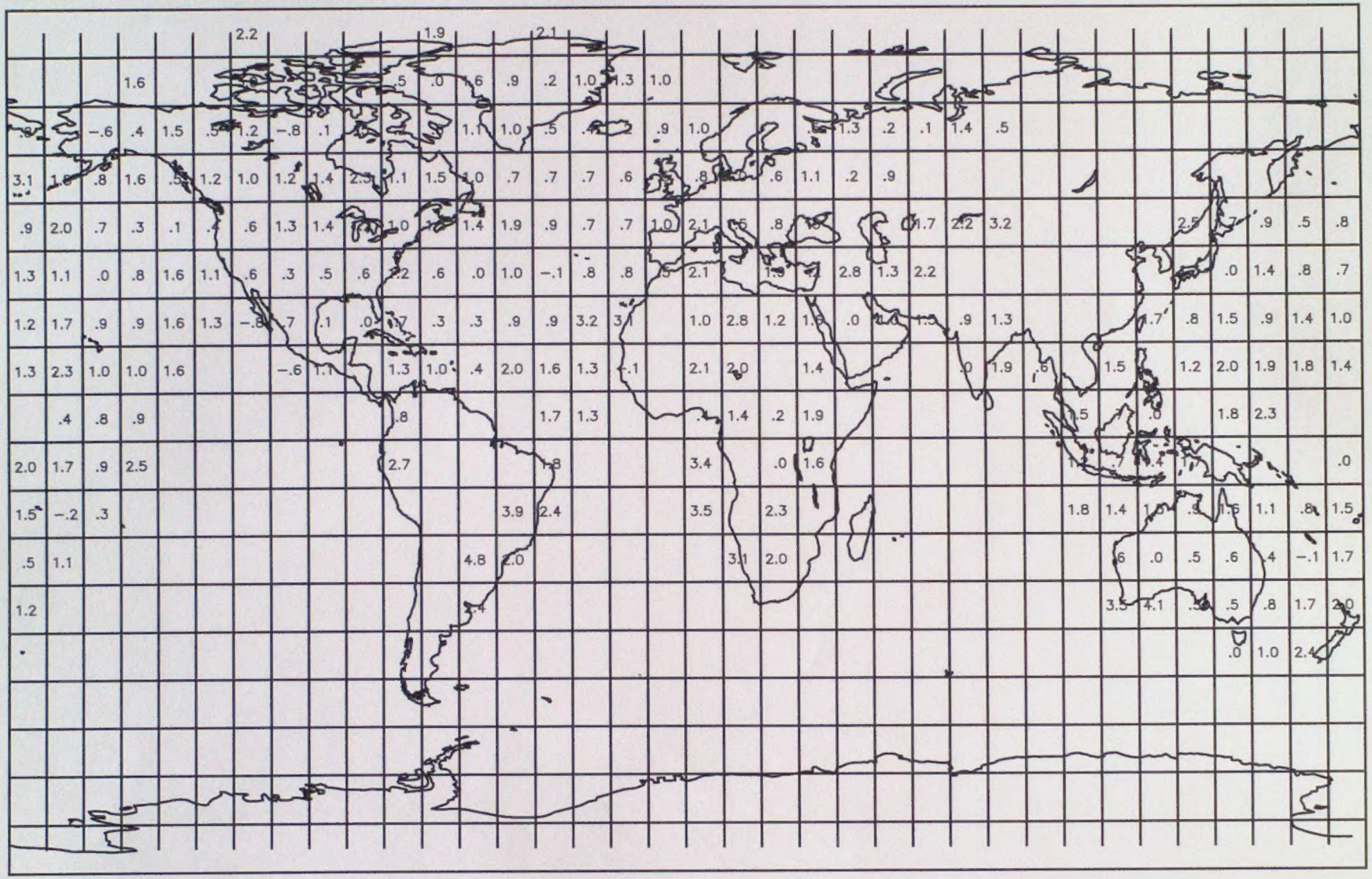
3. Operational run — 250 hPa isotach analysis for 12 UTC 18 May 1995

4. Trial run — 250 hPa isotach analysis for 12 UTC 18 May 1995

5. Operational run — all available wind observations with their callsigns in the layer 350 to 150 hPa between 09 UTC and 15 UTC 18 May 1995.

6. Trial run — all available wind observations with their callsigns in the layer 350 to 150 hPa between 09 UTC and 15 UTC 18 May 1995.

AIRCRAFT REPORTS: MEAN O−B SPEEDS (M/S) BETWEEN 101 AND 400 HPA
MAY 1995 FIGURE 1
OBSERVATIONS WITH O−B VECTOR DIFFERENCE GREATER THAN 60 MPS EXCLUDED
VALUES ARE PRINTED WHERE MORE THAN 30 OBS ARE PRESENT



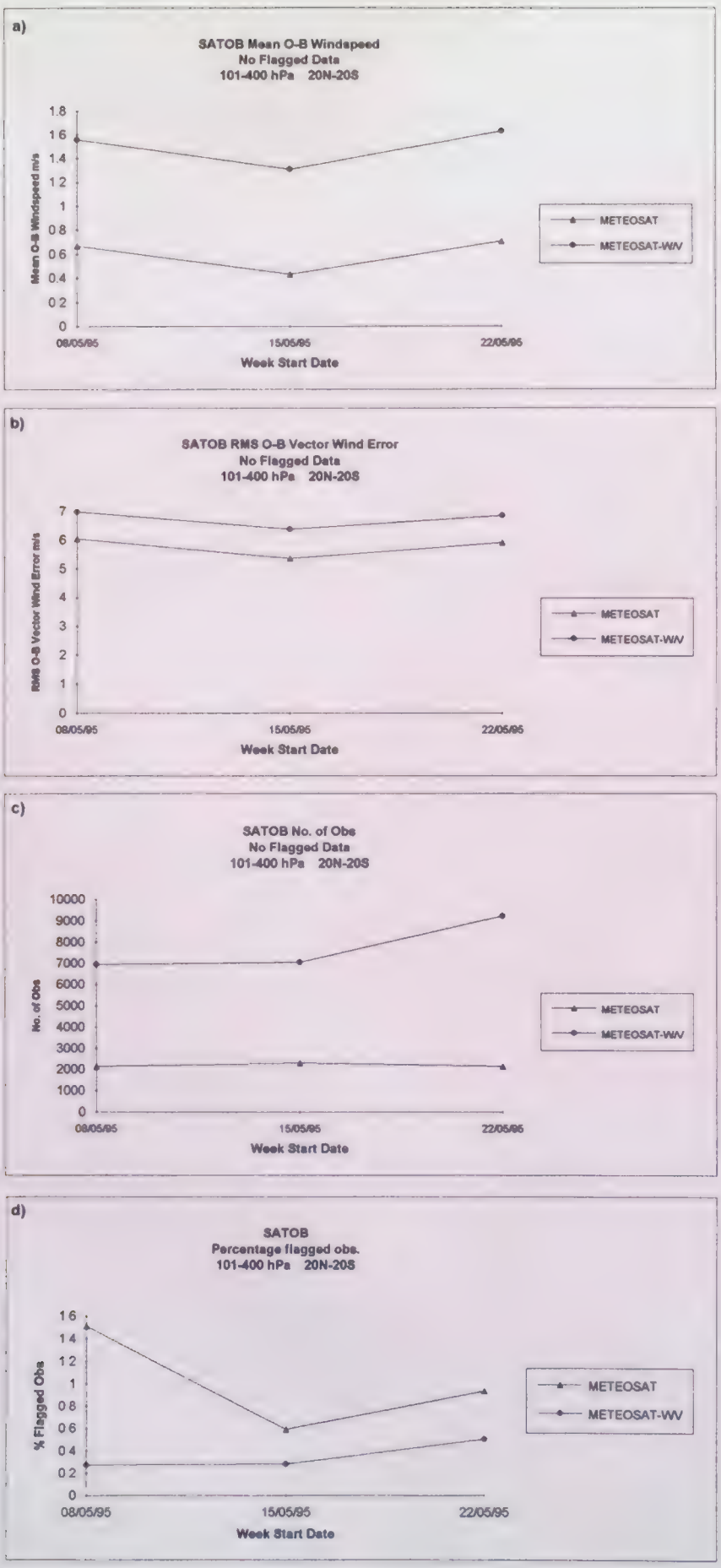

a)
SATOB Mean O-B Windspeed
No Flagged Data
101-400 hPa 20N-20S
Mean O-B Windspeed m/s
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
08/05/95
15/05/95
22/05/95
Week Start Date
METEOSAT
METEOSAT-WV
b)
SATOB RMS O-B Vector Wind Error
No Flagged Data
101-400 hPa 20N-20S
RMS O-B Vector Wind Error m/s
7
6
5
4
3
2
1
0
08/05/95
15/05/95
22/05/95
Week Start Date
METEOSAT
METEOSAT-WV
c)
SATOB No. of Obs
No Flagged Data
101-400 hPa 20N-20S
No. of Obs
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
08/05/95
15/05/95
22/05/95
Week Start Date
METEOSAT
METEOSAT-WV
d)
SATOB
Percentage flagged obs.
101-400 hPa 20N-20S
% Flagged Obs
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
08/05/95
15/05/95
22/05/95
Week Start Date
METEOSAT
METEOSAT-WV

Figure 2

User : cfjl  Date : Tue Aug 15 09:13:17 BST 1995

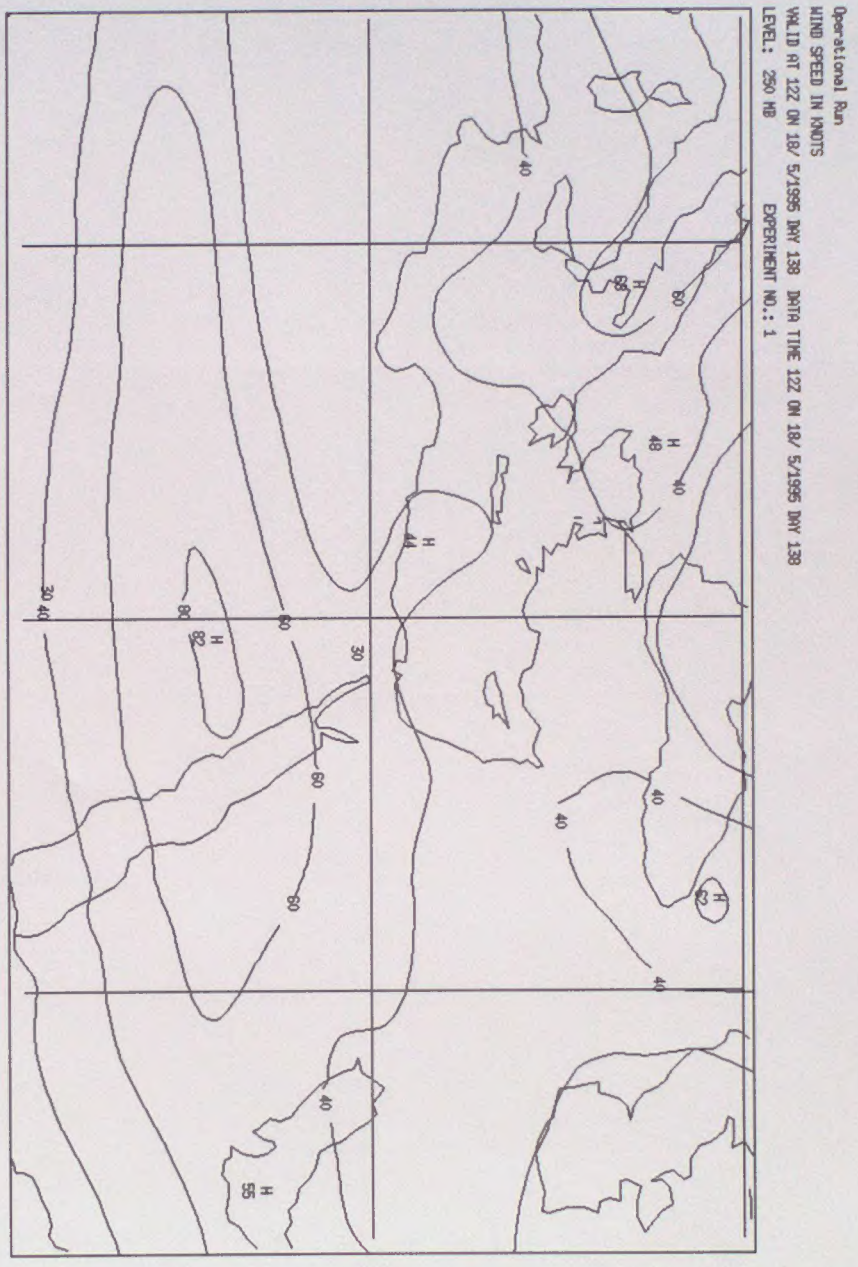



Figure 3

User : cfjl  Date : Mon Aug 14 16:27:05 BST 1995

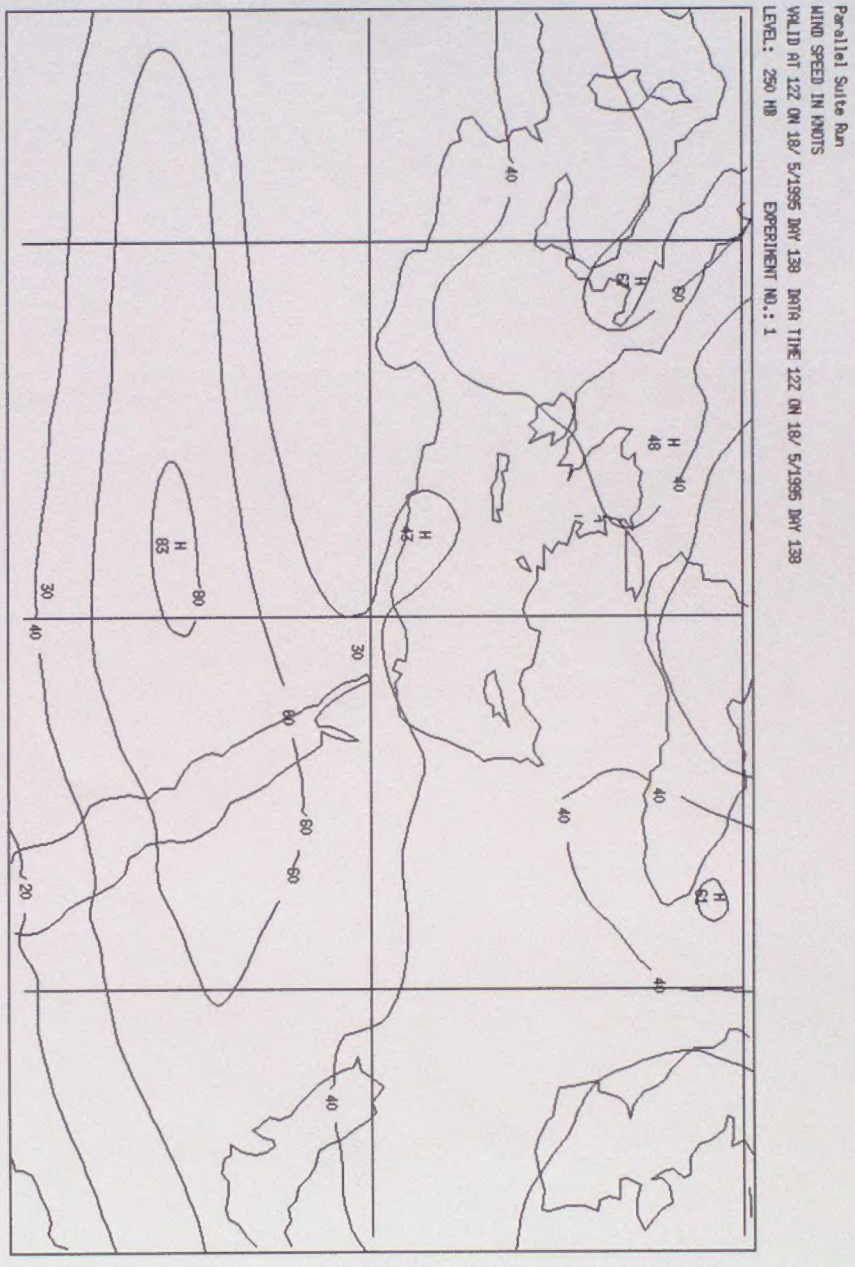
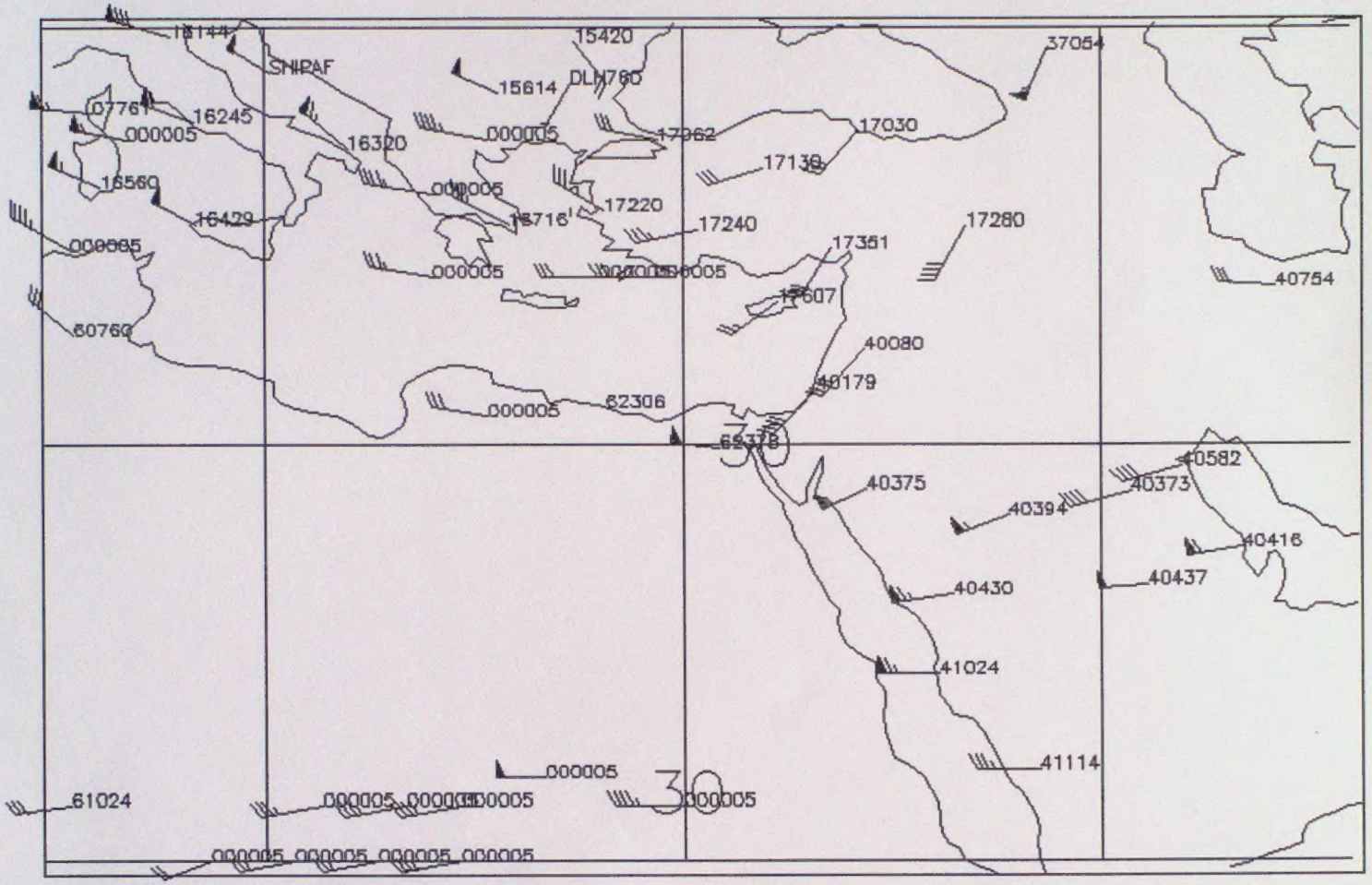



Figure 4

OPD OBSERVATIONS 350.0 MB TO 150.0 MB. SAMPLE
WIND (FULL FEATHER = 10 KTS) AND CALLSIGN 18MAY95:09.00 – 18MAY95:15.00
GRID CENTRE 29.9 30.7 SCALE: 7.59

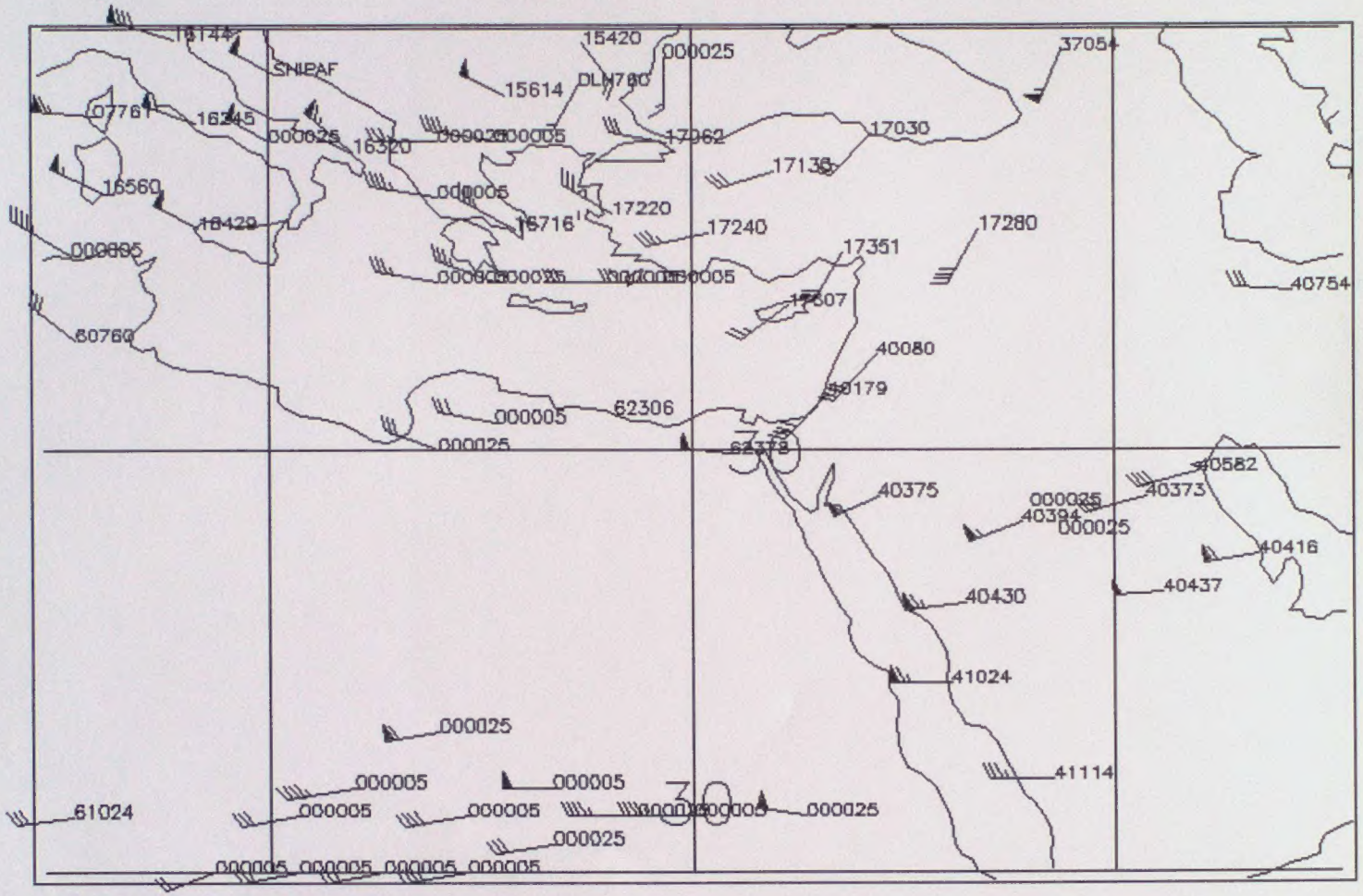



213 OBS 53 PLOTTED
34 R TEMP 0 P PILOT 1 U TSHIP 1 A AIREP 0 M AMDAR
0 C ACARS 17 S SATOB

User : cfjl Date : Tue Aug 15 11:50:40 BST 1995

Figure 5

OPD OBSERVATIONS 350.0 MB TO 150.0 MB. SAMPLE
WIND (FULL FEATHER = 10 KTS) AND CALLSIGN 18MAY95:09.00 – 18MAY95:15.00
GRID CENTRE 29.9 30.0 SCALE: 7.67




213 OBS 63 PLOTTED
34 R TEMP 0 P PILOT 1 U TSHIP 1 A AIREP 0 M AMDAR
0 C ACARS 27 S SATOB

User : cfjl Date : Tue Aug 15 11:47:53 BST 1995

Figure 6